## REMARKS

Claims 1-14 are currently pending in the above-identified patent application. In the subject Office Action, the Examiner rejected claims 1-6, and 8-13 under 35 U.S.C. 103(a) as being unpatentable over Silvast (U.S. Patent No. 4,592,064) in view of Lo (U.S. Patent No. 4,940,893), since the Examiner asserted that claims 1 and 8 and Fig. 1 of Silvast discloses pulsed laser (30) with a chosen power, pulse width and wavelength for generating atoms/ions and directing the laser radiation into the atoms/ions so that an atomic excitation is produced where selected inner-shell electron atomic electrons are removed from the atoms without the removal of all of the electrons in the next outermost shell, thereby generating a hollow atom array having a population inversion from which a chosen wavelength of radiation is emitted and amplified (Col. 2, lines 47-49), and wherein a self-trapped plasma channel region (28) having a nonlinear mode of confined propagation for the chosen wavelength of amplified radiation is formed. However, the Examiner stated, Silvast does not disclose controlling atomic clusters.

The Examiner continued by stating that Lo discloses generating atomic clusters having chosen size and density, controlling the density of the atomic clusters (Col. 3, lines 55-62), and controlling the density of plasma electrons (Col. 4, lines 26-28), resulting in control of the pulse width, wavelength and power of the laser radiation such that the chosen wavelength of amplified radiation is tunable over the wavelengths for the hollow atom array.

Claims 2 and 9 were rejected by the Examiner since the Examiner stated that Silvast discloses choosing the atomic size (determines the collision cross section) to minimize the laser intensity required to excite substantially all of the atoms in the cluster (Col. 8, lines 16-34).

Claims 3, 4, 10 and 11, were rejected by the Examiner since the Examiner asserted that Silvast discloses choosing the pulse width such that atomic excitation occurs on a timescale which is short compared with recombination processes in the plasma produced (Col. 4, lines 14-21).

Claims 5 and 12 were rejected by the Examiner since the Examiner stated that Silvast discloses selecting the atoms so a chosen wavelength is emitted and amplified (Col. 2).

Claims 6 and 13 were rejected by the Examiner since the Examiner asserted that Silvast discloses the use of heavy atoms (Col. 2, lines 26-39), and concluded that it would have been obvious to one of ordinary skill in the art at the time the invention was made to use controlled atomic clusters as disclosed in Lo with the device disclosed in Silvast to obtain a laser emitting light in the x-ray spectrum (Col. 3, lines 36-41).

Claims 7 and 14 were rejected under 35 U.S.C. 103(a) as being unpatentable over Silvast in view of Lo as applied to the claims above, and further in view of Ota (U.S. Patent No. 6,594,334), since the Examiner asserted that Silvast and Lo do not disclose Xe atoms, while Ota discloses the use of Xe atoms for a laser (Abstract) in the 248 nm spectrum (Col. 5, lines 26-30) to suppress the deterioration of optical characteristics (Col. 2, line 54), and concluded that it would have been obvious to one of ordinary skill in the art at the time of the invention to use Xe atoms as disclosed in Ota for the atomic clusters disclosed in Lo for improved suppression of optical deterioration as disclosed in Ota.

Applicants respectfully disagree with the Examiner concerning these grounds of rejection for the reasons to be set forth hereinbelow. Reexamination and reconsideration are respectfully requested.

Briefly, the present invention includes a method and apparatus for generating ultrabright multikilovolt coherent tunable x-radiation. Physical evidence, that includes (a) the observation of strong enhancement of selected spectral components of several $Xe^{q+}$ hollow atom transition arrays (q = 31, 32, 34, 35, 36, 37) radiated axially from confined plasma channels, (b) the measurement of line narrowing that is spectrally correlated with the amplified transitions, (c) evidence for spectral hole-burning in the spontaneous emission, a manifestation of saturated amplification, that corresponds spectrally with the amplified lines, and (d) the detection of an intense narrow ($\delta\theta_x$ ~ 0.2 mr) directed beam of radiation, (1) experimentally demonstrates amplification of multikilovolt x-rays for wavelengths

between $\lambda \sim 2.71$ and $\lambda \sim 2.93$ Å ($\hbar\omega_x \cong 4230$–$4570$ eV); and (2) proves the feasibility of a compact x-ray illuminator. The measurements also ($\alpha$) establish the property of tunability in the quantum energy over a substantial fraction of the spectral region exhibiting amplification ($\Delta\hbar\omega_x \sim 345$ eV); and ($\beta$) demonstrate the coherence of the x-ray output through the observation of a canonical spatial mode pattern. An estimate of the peak brightness achieved in these initial measurements gives a value of $\sim 10^{31}$–$10^{32}$ photons·s$^{-1}$·mm$^{-2}$·mr$^{-2}$ (0.1% Bandwidth)$^{-1}$, a magnitude that is $\sim 10^{7}$–$10^{8}$-fold higher than presently available synchrotron technology.

Hollow atoms are atoms (ions) that intrinsically possess an "inverted" electronic configuration consisting of deeply bound inner-shell vacancies, perhaps multiple, with the simultaneous retention of several electrons in relatively weakly bound outer orbitals. These states are suited for the prompt emission and amplification of x-rays.

Turning now to the rejection of claims 1-6, and 8-13 under 35 U.S.C. 103(a) as being unpatentable over Silvast (U.S. Patent No. 4,592,064) in view of Lo (U.S. Patent No. 4,940,893), applicants wish to direct the Examiner's attention to Fig. 3 and Col. 3, lines 48-53, where it is stated: "The target **36** is mounted on a rod **38** which extends through the other end of transverse segment **12** for manipulation purposes. The focused output of laser **30** impinges upon the target **36** and generates soft X-rays **40** which are absorbed by the active medium **28** in a fashion described later." Further, in Col. 4, lines 7-36, it is stated: "In this case, the intensity of the X-rays should also be sufficient to create a population inversion (optical gain) between the upper laser level and the lower laser level, the energy separation of which corresponds to the wavelength of the optical output **24**. To this end the X-rays **40** are supplied as pulses, the duration of which should be less than the lifetime for the upper laser level. Pulse durations ranging from about 10 nsec to 70 psec have been found useful, but even shorter or perhaps longer pulse duration may be suitable depending upon the particular active medium and the density of electrons generated by the X-rays (i.e., electron collisions with ions in the upper laser levels tend to shorten the lifetime of that state.). As an illustration, consider

the energy level scheme for Cd shown in FIG. 3. Illustratively, the neutral Cd ground state $4d^{10}5s^2\ ^1S_0$ is the target state, the singly ionized $Cd^+$ doublet states $4d^95s^2\ ^2D_{3/2}$ and $^2D_{5/2}$ are the upper state levels, and the singly ionized $Cd^+$ doublet states $4d^{10}5p\ ^2P_{1/2}{}^0$ and $^2P_{3/2}{}^0$ are the respective lower laser levels which are optically coupled by allowed transitions at 3250 Å and 4416 Å, respectively. Prior to excitation, the active medium **28** consists primarily of neutral Cd atoms $Cd^0$ in the ground state. The X-rays **40** are absorbed by the neutral Cd atoms in the ground state (in this case, the target state) causing d-electrons in the fourth shell to be preferentially removed from the atoms leaving them as a singly ionized species $Cd^+$ in the upper laser levels.", and in Col. 4, line 65 to Col. 5, line 13, it is stated: "In an alternative embodiment, the laser 42 may be employed as a transfer laser to increase the energy of the $Cd^+$ ions from the $^2D_{3/2}$ and $^2D_{5/2}$ levels to higher energy states, the $4d^95s5p\ ^2P_{1/2}{}^0$ and $^2P_{3/2}{}^0$ states, which are the upper laser levels. These states typically have lifetimes of a few nanoseconds or less and, as noted above are not metastable. In this configuration the $^2D$ states are an intermediate level rather than the upper laser level, and the $4d^{10}5s\ ^2S_{1/2}$ $Cd^+$ ground state is the lower laser level. The upper laser levels are reached by pumping the $^2D$ intermediate states with a transfer laser at 2008 Å, 2205 Å or 2284 Å. The transfer laser should apply to the active medium optical pulses of duration shorter than the lifetime of the upper laser level. Well-known dye lasers and Raman shifted excimer lasers are suitable transfer lasers. Lasing is expected to occur at 838 Å and 840 Å."

Clearly, Silvast teaches: (1) soft X-ray photoionization, generated by high-power, pulsed laser-produced plasma, for preferentially removing inner-shell d-electrons from neutral atoms leaving them singly ionized in a $^2D$ state, and producing a population inversion with respect to lower lying $^2p$ state irradiation, and giving rise to visible and ultraviolet laser radiation in species such as Cd and Zn; and the (2) the use of a transfer laser to pump the excited D-state to a still higher P-state from which transitions to an S-ground state permit lasing at VUV wavelengths of less than 1000 Å, in species such as Cd, Zn and Hg. Thus, the X-rays are absorbed by the lasing medium, not emitted as laser radiation, and higher

frequency lasing is anticipated to occur only through the use of a second pump laser.

Applicants' claim 1 specifies in part: "directing the laser radiation into the atomic clusters wherein rapid atomic excitation is generated having selected inner-shell electron atomic electrons being removed from the atoms without the removal of all of the electrons in the next outermost shell, thereby generating a population inversion from which a chosen wavelength of x-radiation is amplified or spontaneously generated, and wherein the laser radiation generates and propagates in a self-trapped plasma channel region additionally having a nonlinear mode of confined propagation for the chosen wavelength of x-radiation;" (emphasis added by applicants). As stated hereinabove, several $Xe^{q+}$ hollow atom transition arrays (q = 31, 32, 34, 35, 36, 37) are generated; that is, 31-37 electrons are ejected from Xe atoms. Applicants therefore believe that Silvast teaches away from the present claimed invention.

Claims 7 and 14 were rejected under 35 U.S.C. 103(a) as being unpatentable over Silvast in view of Lo as applied to the claims above, and further in view of Ota (U.S. Patent No. 6,594,334), since the Examiner stated that Ota discloses the use of Xe atoms for a laser in the 248 nm spectrum (Col. 5, lines 26-30) to suppress the deterioration of optical characteristics (Col. 2, line 54).

Lo teaches a method and apparatus for forming coherent assemblies of atoms or molecules. Lo also discloses directing laser radiation to a surface outside of the nozzle that generates the assembly of atoms or molecules, thereby generating electrons having a small energy spread by means of the photoelectric effect. These electrons are accelerated or decelerated by an applied voltage. Ota describes the generation of 100 nm incoherent light from Xe gas using focused laser radiation as an excitation source for purposes of lithography.

Applicants respectfully believe that the Examiner has failed to make a proper *prima facie* case for an obviousness-type rejection under 35 U.S.C. 103(a), since the Examiner has combined a reference which clearly teaches away from the present claimed invention with other references which do not remedy this situation.

Moreover, the combination of Lo and Ota do not render obvious the present claimed invention.

For these reasons, applicants believe that claims 1-14, as originally filed, are in condition for allowance, and such action by the Examiner at an early date is earnestly solicited. Reexamination and reconsideration are respectfully requested.

Respectfully submitted,
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